Electronic Version 1.1

Stylesheet Version v1.1.1

Description

ETHANOL PRODUCTION PROCESS UTILIZING SECONDARY TREATMENT AGENTS TO PRODUCE VALUE ADDED BY-PRODUCTS

TECHNICAL FIELD

[0001] This invention relates in general to ethanol production processes that produce ethanol and a whole stillage stream, and more particularly to ethanol production processes having enhanced value products produced during the fermentation step of the ethanol process and recoverable from the whole stillage stream.

BACKGROUND ART

[0002] In a conventional ethanol production process such as one utilizing corn as the glucose containing feedstock, the corn is ground to produce a milled corn. This is typically achieved by the use of a hammer mill or other similar conventional milling equipment. Water and enzymes (most commonly alpha amylase) are added to the milled corn and heated to form a liquefied mash. The liquefied mash is then mixed in a fermentation vessel with water, yeast and selected minerals and nutrients to enhance the fermentation of the mash. The fermented product, commonly referred to

as the "beer", is then distilled to produce an ethanol rich stream (about 95% ethanol and 5% water by weight) and a whole stillage. The whole stillage comprises water, as well as the solids resulting from the fermentation. It is typical to centrifuge the whole stillage to remove a substantial portion of the water to form a wet distillers grain. The wet distillers grain includes most of the protein containing solids that is found in the whole stillage. The removed water containing nutrients and other solids generally known as the thin stillage is sent to an evaporator to remove a substantial portion of the water. The remaining nutrients and solids called the syrup are then combined with the wet distillers grain. The combined syrup and wet distillers grain is sent to a dryer to produce a dry protein containing animal feed called distiller dried grain solubles (DDGS).

[0003] Because of the economics involved in the current processes, such ethanol production processes have remained economically viable due in part to government subsidies. Efforts to improve the economic viability of these processes have been addressed, but there still remains demand for the gain of further economic benefit from the use of an ethanol production process.

INDUSTRIAL APPLICABILITY

[0004]

Therefore, one object of this invention is to provide an improved ethanol production process that results in the production and recovery of valuable products from the whole stillage stream. Other objects and advantages of this invention shall become apparent from the ensuing descriptions of the

invention.

[0005] Accordingly, an improved ethanol producing process is disclosed wherein a sucrose or starch-containing feedstock is hydrolyzed in the presence of a known ethanol fermentation agent and a secondary treatment agent to produce ethanol and a whole stillage that can be treated to recover valuable products. More particularly, the secondary treatment agent can be a bacteria, enzyme or fungi that can be added to the liquid mash during the formation of the liquid mash or during the fermentation step to produce a whole stillage containing the desired valuable compounds, or precursors thereof, that can then be recovered from the whole stillage by known centrifuging or other separation processes. The secondary treatment agent is selected from that group of bacteria, enzyme or fungi that do not interfere with the ethanol producing activity of the fermentation agent. In addition the secondary treatment agent must be active under fermentation conditions; more particularly, 20°C - 40°C and a pH from about 4.0 to about 6.5, and must be active in the presence of ethanol.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The accompanying drawings illustrate a known prior art process for the production of ethanol.

[0007] Figure 1 is a schematic illustrating a conventional prior art ethanol production process.

BEST MODE FOR CARRYING OUT THE INVENTION

[0008] Without any intent to limit the scope of this invention, reference is made to the figures in describing the preferred embodiments of the invention utilizing corn as the glucose containing feedstock. The process described herein can also be used with other glucose containing feed stocks such as bagasse, sugar cane, grains, and other sucrose containing materials, such as sugar cane and sugar beets.

[0009]

In a conventional ethanol production process as illustrated in Figure 1, a starch-containing feedstock **1**, such as corn, is fed to a grinder **2** to produce a milled corn **3**. The milled corn **3** is then send to a mixer **4** where water **5**, as well as enzymes **6**, are added to produce a liquid mash **7**. The liquid mash **7** is then sent to a fermentation vessel **8** where the desired yeast and additional enzymes **9**, as well as the minerals and nutrients **10** necessary for efficient fermentation, are added. After the desired amount of fermentation has been completed the resulting product **11** commonly referred to as the "beer" is sent to a distillation unit **12** where an ethanol rich (about 95% ethanol by weight) stream **13** is separated from the remaining fermented solids and water. The remaining fermented solids and water is generally known as the whole stillage **14**. The whole stillage **14** is treated to produce an animal feed commonly known as DDGS. The most common method to treat the whole stillage **14** is to separate the whole stillage **14** by centrifuge **15** to form two separate streams. The first is known as the wet distillers grain **16**. The wet distillers grain **16** includes most of the solids and some of the water found in the whole stillage **14**. The second stream is known as the thin stillage stream **17**. It includes the

minerals, nutrients, yeast and the remaining water that was found in the whole stillage **14**. In a typical process the thin stillage stream **17** is sent to evaporator **18** where water **19** is removed and the remaining solids or syrup **20** are combined with the wet distillers grain **16** and sent to a drum dryer **21**. The dryer **21** is typically operated with the hot air having an inlet temperature at about 1000 ^{o} F. - 1200^{o} F. The hot air will remain in contact with the wet distillers grain **16** and syrup **20** for approximately five minutes before exiting the dryer **20** having an exhaust temperature at about 200 ^{o} F. - 225 ^{o} F. At these conditions the protein contained in the dried solids **24** are denatured and are only good for use in animal feed known as DDSG. In addition any water vapor **22** and VOC **23** in the wet distillers grain **16** and syrup **20** is volatized and either released to the atmosphere or passed through expensive conventional thermal oxidizers (not shown).

[0010]

The process of this invention involves the addition of predetermined fermentation agents (bacteria, enzymes, and fungi) to the liquid mash before or during the fermentation step. The secondary treatment agents selected should not interfere to any significant degree with the activity of the fermentation agent selected to convert the carbohydrate matter into ethanol. The secondary treatment agent selected should also be viable and effective in converting the liquid mash under the operating conditions found in the fermentation step. Such conditions typically include temperatures from about 20°C to about 40°C, and a pH between about 4.0 to about 6.5. Finally, the secondary treatment agent selected should be one known for the conversion of at least some of the constituents in the

whole stillage to the desired valuable by-product or precursor thereof.

[0011] The following are examples of valuable by-products that can be obtained from the whole stillage through the selection of the secondary treatment agent: yeast extract, vitamins (e.g., thiamin, riboflavin, botin, pyridoxine, niacin, glutathione, and pantothenic acid), corn proteins, fructooligosaccharides, xanthan gum, antibiotics (e.g., ampicillin, erythromycin, penicillin, tetracycline, northienamycin, acanthomycin, lincomycin, rifamycin, gardimycin, mycoplanecin, gentamycin, aminocyclitol, prodigisin, and nocardicin), organic acids (e.g., citric acid, tartaric acid, and malic acid), amino acids (alanine, arginine, aspartic acid, cysteine and cystine, glutamic acid, histidine, leucine, lysine, methionine, phenylalanine, serine, and tryptophan), nucleic acids (e.g., guanosine), alcohols (e.g., mannitol, ergosterol and cholesterol), carbohydrates (e.g., glucan, maltopentaose, pullulan, glucides, emulsifying agents, cyclodextrin, flavonoid glycosides), organic compounds (e.g., zeaxanthin, pyridoxine, sapogenins and ergot alkaloids), enzymes (amylase, lipase, andgalactosidase), and steroids (e.g., insulin and interferon).

[0012] When present in moderate to high concentrations, such as are present in the fermentation step, ethanol is known to denature many microorganisms and enzymes. Therefore, the secondary treatment agent must be selected from a group of bacterial, enzymes and/or fungi that can withstand the denaturing properties of the ethanol. Secondly, they must have the ability to convert at least some of the constituents forming the whole stillage into the desired valuable by-product or its precursor. Thirdly, they must be

active under the operating conditions in the fermentation vessel; i.e., about 20°C to about 40°C and pH of about 4.0 to about 6.5.

[0013] The following are illustrative examples of secondary treatment agents that could be used to produce particular valuable by-products from the whole stillage.

[0014] Example 1. In a process that involves contacting a glucose-containing substrate (such as corn) with a mixture of a known ethanol producing yeast and the enzyme cyclodextrin glucosyl transferase, the reaction is purified by removal of the yeast bodies and ethanol to yield a product containing cyclodextrin polymers. The finished product would contain alpha-cyclodextrin (6 Glucose units), beta-cyclodextrin (7 Glucose units), and gamma-cyclodextrin (8 Glucose units). The enzyme for this reaction can be the purified form, or a simultaneous fermentation of an organism that produces the enzyme, including Bacillus circulans, Bacillus stearothermophilus, Bacillus sp. Most notable are the enzymes from B. Subtilis, B. Stearothermophilus, and Klebsiella oxytoca. The pH and termperature optima for activity are the same as for normal ethanol production using Saccharomyces cerevisiae (pH 5.0, 350C - 40°C).

[0015] Example 2. The use of the fungi Penicillium chrysogenum with the Saccharomyces cerevisiae during the fermentation stage under normal ethanol production would result in the production of ethanol and Penicillin G.

[0016] Example 3. The use of the bacteria Lactobacillus cellobiosus,

Lactobacillus plantarium, and Acetobacter pasteurians, Bacillus pumilus and B. licheniformis with the Saccharomyces cerevisiae during the fermentation stage under normal ethanol production would result in the production of ethanol, acetic acid, and lactic acid. This is a chocolate flavor.

[0017] There are other obvious specific bacteria, enzymes and/or fungi having the desired characteristics that could be used to produce particular desired products.